MESON INTERFEROMETRY AND THE QUEST FOR QUARK-GLUON MATTER

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We point out what we may learn from the investigation of identical two-particle interferometry in ultrarelativistic heavy ion collisions if we assume a particular model scenario by the formation of a thermalized quark-gluon plasma hadronizing via a first-order phase transition to an interacting hadron gas. The bulk properties of the two-pion correlation functions are dominated by these late and soft resonance gas rescattering processes. However, we show that kaons at large transverse momenta have several advantages and a bigger sensitivity to the QCD phase transition parameters.

1 HBT-radius parameters and their relevance for the quest for quark-gluon matter

Correlations of identical particle pairs, also called HBT interferometry, provide important information on the space-time extension of the particle emitting source as for example in ultrarelativistic heavy ion collisions. In this case, QCD lattice calculations have predicted a transition from quark-gluon matter to hadronic matter at high temperatures. For a first-order phase transition, large hadronization times have been expected due to the associated large latent heat as compared to a purely hadronic scenario. Entropy has to be conserved while the number of degrees of freedom is reduced throughout the phase transition. Thus, one has expected a considerable jump in the magnitude of the HBT-radius parameters and the emission duration once the energy density is large enough to produce quark-gluon matter[1]. The two alternative space-time evolution pictures, with and without a phase transition, are illustrated in Fig. 1 in the z-t-diagram. After the collision of the two nuclei, each with nucleon number A, the system is formed at some eigen-time τ (indicated by the hyperbola) and the initial expansion proceeds either in a hadronic state (left-hand side) or in a state dominated by partonic degrees of freedom, for example a quark-gluon plasma (QGP) (right-hand side). In the latter case, the formation of a mixed phase, leads to large hadronization times and thus to rather long emission durations. The freeze-out is defined as the decoupling of the particles, i.e., the space-time coordinates of their last (strong) interactions. As a consequence, HBT interferometry and in partic-

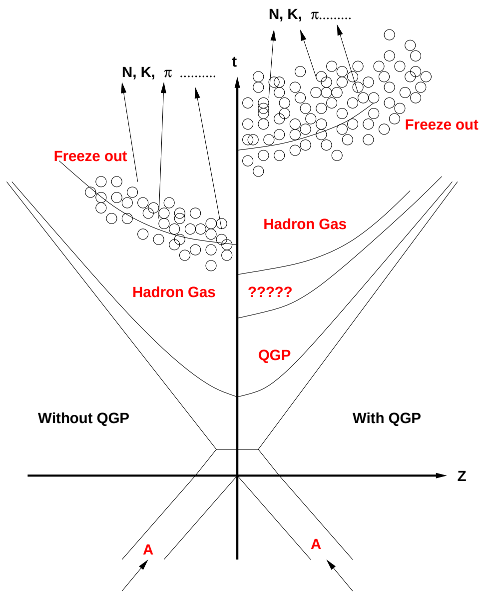

Figure 1. Illustration of the space-time evolution in the z-t-diagram with (right) and without (left) a phase transition[2]. Proceeding through a first-order phase transition with a large latent heat should lead to large hadronization times, thus yielding eventually large HBT-radius parameters and emission duration.

ular the excitation function of the HBT-parameters have been considered as an ideal tool to detect the existence and the properties of a transition from a thermalized quark-gluon plasma to hadrons.

2 The importance of late soft hadronic rescatterings for two-particle correlations at small relative momenta

Here, we discuss calculations based on a two-phase dynamical transport model that describes the early quark-gluon plasma phase by hydrodynamics and the later stages after hadronization from the phase boundary of the mixed phase by microscopic transport of the hadrons [1]. In the hadronic phase, resonance (de)excitations and binary collisions are modeled based on cross sections and resonance properties as measured in vacuum. Fig. 2a shows the pion HBT-parameters R_i as a function of the transverse momentum K_T as calculated from the rms-widths of the freeze-out distributions [1]. $R_{\rm out}$ probes the spatial and temporal extension of the source while $R_{\rm side}$ is only sensitive to the spatial

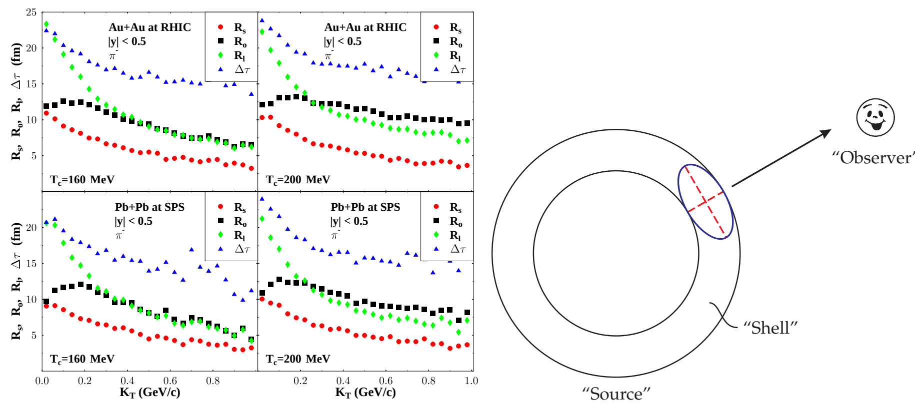

Figure 2. (a) Pion HBT-radius parameters and emission duration as a function of K_T as calculated from the rms-radii of the *QGP+hadronic rescattering* model freeze-out distributions. The four different panels correspond to RHIC (top) and SPS (bottom) energies and $T_c \simeq 160\,\mathrm{MeV}$ (left) and $T_c \simeq 200\,\mathrm{MeV}$, respectively. (b) Illustration of a shell-like emission. The surface emission geometry corresponds to small values of the ratio $R_{\mathrm{out}}/R_{\mathrm{side}}$, indicated by the two dashed lines in the emission volume element relevant for an observer. The dashed line in the direction to the observer corresponds to the *out* direction, the orthogonal line is the *side* direction.

extension. Thus, the ratio $R_{\mathrm{out}}/R_{\mathrm{side}}$ gives a measure of the emission duration. Here, we focus on the fact that for all initial conditions considered (SPS or RHIC energies and critical temperatures $T_c \simeq 160\,\mathrm{MeV}$ or $T_c \simeq 200\,\mathrm{MeV}$) the HBT-parameters appear to be rather similar. This demonstrates that a long-lived hadronic phase dominates the bulk dependencies of the pion HBT-parameters rather than the exact properties of the QCD phase transition. In addition, the ratio $R_{\mathrm{out}}/R_{\mathrm{side}}$ increases as a function of K_T up to values of about $1.5 - 2$ indicating the large emission durations. However, experimental data at RHIC [3,4] show a completly new behaviour (not seen at SPS). The $R_{\mathrm{out}}/R_{\mathrm{side}}$ ratio decreases and even is smaller than unity. This would hint at a rather explosive scenario with very short emission times, not compatible with a picture of a thermalized quark-gluon plasma hadronizing via a first-order phase transition to an interacting hadron gas. Rather a shell-like emission as illustrated in Fig.2b would be prefered. Thus, the further study of HBT-interferometry will provide extremly important information e.g. on the hadronization process or the question of thermalization in ultrarelativistic heavy ion collisions.

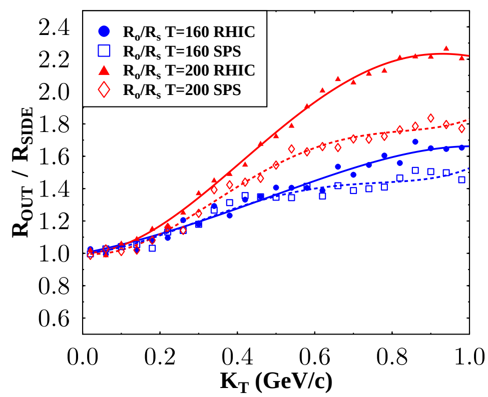

Figure 3. Ratio $R_{\rm out}/R_{\rm side}$ for kaons as a function of transverse momentum K_T as calculated with the *QGP+hadronic rescattering model* for SPS and RHIC and critical temperatures $T_c \simeq 160$ MeV and $T_c \simeq 200$ MeV.

3 Advantages of Kaons

Besides many experimental advantages kaons are less contaminated by long-lived resonances and escape the opaque hadronic phase easier. Thus, $\sim 30\%$ of the kaons at $K_T \sim 1$ GeV/c are directly emitted from the phase-boundary. Complementary, large K_T kaons and their $R_{\rm out}/R_{\rm side}$ ratio exhibit a strong sensitivity on the QCD equation of state as shown in Fig. 3.

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